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A Paper by
WILLIAM G. SNOW

Read May 24, 1910, at Cornell University
In the Course on
Sanitary Science and Public Health
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I am to speak to you today on VENTILATION IN ITS RELATION TO HEALTH. The subject suggests a marshalling of figures and an array of facts, but I will not bore you with these. While it is admitted by all thinking people that ventilation must promote health, it is not realized to what extent the converse of this statement is true; that is, to what extent ill health is caused by insufficient or ineffective ventilation. When one considers how little time is spent out of doors by urban dwellers during our colder months, is it not of the utmost importance that their surroundings while indoors should be made healthful by plenty of sunlight and fresh air?

I will say at the outset that I shall have occasion to quote rather copiously from various authorities on ventilation and the quality of air and believe this is necessary in order to bring out clearly the data on which any conclusions are to be based.

In other words, in discussing a subject like the one before us, we want not the opinion of one man alone, but the conclusions of a number of persons who have studied the matter.

Therefore, if the quotations to be given appear somewhat protracted, let the above remarks be borne in mind.

Taking up first:

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Causes of Atmospheric Vitiation

The cause of which we most commonly hear is the accumulation of carbon dioxide. When we realize that this gas is increased over a hundred fold in the air passing through the lungs, it is not surprising that this component of the atmosphere accumulates rapidly in occupied rooms.

An interchange of gases takes place in the lungs, called the respiratory exchange, oxygen passing from the air to the body and carbon dioxide from the lung-cells to the air about to be exhaled. The air discharged from the lungs is saturated with water-vapor.

In proportion to their weight children give off about twice as much carbon dioxide as adults, hence the importance of adequate ventilation in rooms occupied by little ones. Professor Woodbridge, of the Massachusetts Institute of Technology, states that "the actual amount of air breathed may be averaged as 15 cu. ft. per hour, and that 0.6 cu. ft. of carbon dioxide is exhaled per hour by a person in repose; that the vapor elimination by a person at rest is about 1½ oz. per hour, about one-fourth of the vapor elimination coming from the lungs."

He states that "about one-sixty-seventh of the body's weight of matter passes through the pores per day as effluvia or organic matter carried out through the pores with the perspiration. It gives a foul odor to crowded or poorly ventilated rooms. The more active the perspiration the more free the effluvia elimination. An assembly of 1000 adults gives to the air each hour nearly 100 lbs. of perspiration vapor."

Woodbridge says further that "high humidity increases the amount of decomposable matter present in an occupied enclosure, it hastens its decomposition, it accelerates its diffusion and intensifies its putrefying odor."

As to the accumulation of carbon dioxide in occupied rooms to which atmosphere vitiation is commonly attributed, the late A. R. Wolff, of New York, stated: "It is not the presence of the carbon dioxide itself which causes injury, but the bad company associated with its presence.

The fact is that besides the carbon dioxide exhaled with the expired air there are also organic matters and aqueous and other vapors, and at the same time there are given off from the pores of the skin organic secretions and moisture, all of which taken together, and possibly acted upon and made more detrimental in effect by the heat of the room, vitiate the atmosphere and jointly are the sources of the trouble. . . . . They go hand in hand with the amount of carbon dioxide in the room."

As to the degree of vitiation, the relative purity of the atmosphere is generally expressed in the number of parts by volume of carbonic-acid gas contained in 10,000 parts or volumes of air. The proportion of this gas contained in the atmosphere may be easily determined by several methods, and it affords a fairly good index of the relative number of micro-organisms present and of the efficiency of ventilation.

In crowded rooms with the usual accompanying high temperatures, the water-vapor from the lungs and the perspiration vapor soon saturate the air, and it is to this combination of temperature and humidity that some writers attribute most of the discomfort experienced.

That moisture is present in crowded rooms in cold weather is evidenced by the condensation on windows. When it is considered that this moisture is chiefly from exhalations from the lungs and the eliminations from the bodies of those present, it would seem evident that such a component of the atmosphere must not only produce discomfort but be positively harmful.

Macfie, in his recently published work, "Air and Health," says: "Air containing merely the carbon dioxide and moisture usually contained in vitiated air will not produce the effect of vitiated air, and vitiated air, therefore, must contain an additional constituent. This additional constituent, though undetected by chemists, is probably detected by the nose, for it is well known that air is oppressive and harmful not so much in proportion to the amount of carbon dioxide and moisture it contains as in propor-

tion to its *smelliness*. The very fact that the nose is so sensitive to such odors would seem to suggest their harmfulness."

In addition to the carbonic-acid gas, the effluvia and the humidity mentioned, which affect the comfort and well-being of persons, are the dusts to which Dr. T. Mitchell Prudden's little book, "Dust and its Dangers," is devoted. Outer air contains, of course, more or less dust which, when admitted to a building, tends to settle. Dr. Prudden observes "that even ordinarily efficient systems of ventilation do not carry off any considerable proportion of the dust particles from closed, still rooms. . . . and that when, by a system of forced ventilation, we cause large volumes of dust-laden air from out-of-doors to pass through them, we are actually, so far as micro-organisms are concerned, cleansing the air and sending it out much freer from germs than when it entered, these having slowly settled as the air makes its way from the entrance to the exit of the ventilating openings." He says:

"When we consider the comportment of dust particles in closed rooms, we see at once that the great renovating and cleansing agencies which are so efficient out-of-doors are, except on special occasions, absent, namely, the winds and strong air currents and the more or less frequent and prolonged wettings. . . . . A rainfall, to a certain extent, tends to free the air of its germs by washing them down. . . ."

Dr. Prudden points out that "we should always remember that bacteria do not become detached from the surfaces or materials on which they grow or are lodged while these are in a moist condition." He remarks: "Ventilation is slowly becoming recognized as important, but the removal of dust, which in crowded places is very liable to be infectious, is not systematically attended to." The most obvious means to prevent the accumulation of dust within enclosures is to remove it from the entering air.

We have briefly considered the "*causes of atmospheric vitiation.*" Now as to the

Effects of Foul Air on Health and Comfort

Billings observes in "Ventilation and Heating" that "it requires the observation of the effects on the health and life of a number of men exposed to such air for a series of months or years to demonstrate the slow but certain production of throat and lung troubles, the loss of energy and vitality and the shortening of life which are thus produced. These observations have been made on soldiers occupying ill-ventilated barracks and operatives working in close workrooms, and comparison of these results has shown that where any room is occupied by human beings there is a definite, unpleasant animal or musty odor, perceived by a person whose sense of smell is of the usual acuteness and who enters from the fresh outer air, the continued breathing of the air producing such odor will be injurious to health."

Mrs. E. H. Richards of the Massachusetts Institute of Technology states in her book, "Air, Water and Food," "That a permanent or habitual lowering of the oxygen in inspired air must be harmful will be readily seen from a consideration of the office of this gas in the body. (To Lavoisier and Laplace we owe the knowledge that animal heat is derived from a process of combustion. . .)

"By the union of the oxygen with the substance found in the tissues and brought to them by the circulating fluids of the body from digested food, the heat necessary for the life and work of the body is produced. This heat is needed to keep the tissues at the temperature at which they can best accomplish their work, to give mechanical power for the involuntary action of heart and lungs for the process of assimilation and to furnish the energy for all voluntary work and thought."

While the harmful effect of foul air may not be immediate other than its effect on one's comfort or mental acuteness, it is generally conceded that frequent and protracted exposure to such air, as in the case of poorly ventilated school buildings, results physiologically in a lowering of the vitality of the occupants, rendering them

more susceptible to disease and, considered economically, results in a lessened efficiency on the part of both pupils and teachers.

Playfair asserts that, in modern hygiene, "nothing is more conclusively shown than the fact that vitiated atmospheres are the most fruitful sources of disease."

Tuberculosis and pneumonia are most prevalent among persons living or working in unventilated rooms. These diseases are caused by specific bacteria, which for the most part gain access to the air passages by adhering to particles of dust which are inhaled.

As to the physiological effects of close air, Mrs. E. H. Richards in her book referred to observes that "it seems to be indicated that the evil is due to the change in the respiratory quotient and to the consequent change in blood pressure, which interferes with the circulation. (The respiratory quotient is obtained by dividing the volume of carbon dioxide given off by that of the oxygen absorbed and indicates how much of the oxygen has combined with carbon to form carbon dioxide, since one volume of oxygen combines with carbon to form one volume of carbon dioxide.) The rate of exchange is influenced by questions of pressure, exposure, temperature and water-vapor or moisture, muscular activity and the like."

Macfie, in his work, "Air and Health," says: "Let us glance for a moment at the effect of the excess of carbon dioxide and the diminution of oxygen in vitiated air. Has this variation no vicious effect?

"Any one who compares his power of mental work in a pure and in a carbonic-acid-laden atmosphere, even if the latter be dry and cool, will find in the latter a considerable diminution.

"It may be contended that the human constitution becomes in time accustomed to vitiated air, and that much of the ill health ascribed to bad air is really due to other circumstances, such as poor feeding and depressing surroundings, but the difference in health between country poor and city poor, and the improvement in health which always

follows removal of impure air, is sufficient answer to such a contention."

Macfie further says: "Does such vitiated air as is ordinarily breathed in human habitations cause ill health apart from the infectious germs or infectious material it may contain? . . It is, of course, almost universally believed nowadays that indoor air rendered impure by respiration and combustion is harmful to health. To bad air we attribute much of the anaemia, the pallor, the neurasthenia, the general ill health of slum-dwellers and factory workers and most persons engaged in sedentary indoor occupations."

As to the effect of dust, Dr. Prudden says:

"Very moderate amounts of dust particles in sensitive persons cause such a degree of irritation of the respiratory organs as either to deprive them of robust health or predispose them to the acquirement of various diseases which with unirritated lungs they would readily resist.

"As to the bacteria . . . there are unfortunately a few species which, when they once find lodgment in one place or another in the organs of respiration, may grow and multiply, and successfully resisting all the protective agencies of the body, set up distinct, persistent and even fatal disease. Those forms of bacteria which can or in these regions commonly do this, are insignificant in number in comparison with the harmless species with which dust is usually swarming. But few as they are they have an extreme significance. If it were not for these few species of disease-producing bacteria, most people could perhaps afford to be as indifferent as they are to dust and its dangers. . . . ."

It has been pointed out among the causes of atmospheric vitiation and discomfort that high temperature and humidity have much to do with the oppressiveness of the atmosphere in occupied spaces. In this connection I wish to quote from a paper by Dr. Henry Mitchell Smith of Brooklyn, N. Y., read before the Brooklyn Medical Society. Dr. Smith says:—

"Records of the temperature in a large number of houses showed . . that it commonly ranged from 72 to

76°, and at times, in very cold weather, 78° F. was recorded. Startling as are these figures in themselves and contrary to all accepted ideas of the proper conditions for living rooms, yet a puzzling fact was that the sensations of the occupants were frequently not in accord with the readings of the thermometer. Rooms felt chilly when the recorded temperature indicated that they were far too hot. It was often hard to believe that the temperature was above 68° when it was actually 72° and 74°.

"It was at once apparent that some unrecognized factor was responsible for this discrepancy between the temperature recorded by the thermometer and one's sensations. Moreover, it was found that the colder the weather the higher was the average temperature maintained indoors. . . . The reason for this is the insufficient amount of moisture in our rooms in proportion to the temperature (low relative humidity). The colder the weather the lower will be the indoor relative humidity. . . .

"The point to be emphasized is that every time we step out of our houses during the winter season we pass from an atmosphere with a relative humidity of about 30 per cent. into one with a relative humidity of an average of 70 per cent. Such a sharp and violent contrast must be productive of harm, particularly to the delicate mucous membranes of the upper air passages. Watery vapor, what we term moisture, is as much a part of the air as is oxygen; absolutely dry air does not exist in nature. . . . .

"The skin and the mucous membranes of the respiratory passages are the principal sufferers, since these tissues are always kept moist with their own secretions; and from them water is freely abstracted to satisfy this large saturation deficit. . . .

"A moment's consideration shows that the prevailing practice of depending upon the thermometer as the sole guide in the heating of buildings is not only inadequate and unscientific, but it is often misleading. It is not sufficient to know only the temperature if we desire either comfort or health, for the same temperatures produce varying sen-

sations of warmth or cold, depending upon the relative humidity at the time existing.

"It is unscientific and arbitrary to lay down a fixed temperature as a standard for living or sleeping rooms unless the relative humidity is indicated as well. . . .

"Records from steam-heated apartments showed that the relative humidity was sometimes as low as 25 per cent., with a temperature of 78° during a period of very cold weather. . . The high temperature is necessitated by the chilling of the body by the increased evaporation, evaporation being essentially a cooling process.

"It is needless to say how unhygienic as well as uncomfortable is such a distortion of the proper relationship between temperature and relative humidity. By regulating the indoor relative humidity we could keep our room temperature much more nearly stationary, irrespective of the temperature outside. . . Thermostatic temperature control will not fill the requirement, for a constant temperature is constant in its effect only if accompanied by a constant relative humidity. . . Moreover, properly moistened indoor atmosphere lacks all the oppressive dry feeling so characteristic of the average artificially heated room. . . The quieting effect of such an atmosphere is striking. . . .

"It was satisfactorily proved that one may live during the coldest weather with perfect comfort in a room at 65° F. where the relative humidity is kept at about 60 per cent. During the experiments upon the sensations produced by different percentages of saturation, and in order to obtain the opinion of persons having no knowledge of the existing conditions, one room was equipped with a moistening apparatus and the temperature kept at 65° to 68°, with a relative humidity of about 60 per cent. An adjoining room, without a moistening apparatus and heated by an ordinary steam radiator, had an average temperature of 72° to 74°, with a relative humidity of 30 per cent. In every instance and without at all knowing what the temperatures were in the two rooms, the opinion was unhesitatingly expressed

that the first room was several degrees warmer than the second. . . .

"A moment's thought recalls the fact that we often sit out of doors with perfect comfort at a temperature that would cause us to shiver in our rooms in the winter. The relative humidity is the balance-wheel that regulates our comfort at different temperatures in still air. So repeatedly was this demonstrated that it may be accepted as a cardinal rule that if a room at 68° is not warm enough for any healthy person, it is because the relative humidity is too low. . . It is inconceivable that with otherwise perfect means of heating, provision for producing sufficient moisture to maintain a higher relative humidity should have been so disregarded in all but those elaborate systems applicable only to large halls and public buildings. . . ."

Dr. Smith says: "It is amusing to find that in spite of the advantages of a moister atmosphere indoors, objections have been raised against the use of devices for this purpose, on the ground that when the weather is very cold moisture condenses upon the window panes."

As to desirable and practical relative humidities in rooms occupied in winter by persons in health, taking into consideration the cost of maintaining a high relative humidity in cold weather and the trouble from condensation on windows, I am inclined to favor a range from 40 to 50 per cent., according to the weather, rather than the higher relative humidity mentioned in Dr. Smith's paper, viz., 60 per cent. As to the condensation on windows, this will occur during cold weather when the indoor relative humidity is 40 per cent., and even somewhat less. When double windows are used, as is common in northern latitudes, the condensation is much reduced.

Humidity as applied to manufacturing plants was discussed in a very interesting manner by George V. S. Michaelis in a paper entitled, "Sanitary Conditions in Ventilating and Humidifying Cotton Mills." (The National Association of Cotton Manufacturers, September 22-23, 1909.) Mr. Michaelis says, after pointing out the economic waste due to insufficient heating, resulting in chilled

fingers of mill operatives: "Pure air is, however, fully as important in influencing product as warm fingers. Adequate ventilation, therefore, is as vital a factor in summer as in winter.

"Curiously enough, humidification has developed in the minds of most mill men as a purely mechanical proposition, that is to say, in its relation to improved fibre conditioning. Adequate humidity has been recognized as increasing output through strengthening the yarn, reducing electrical tension, improving the yarn by causing the fibres to engage together more closely and by giving greater elasticity at the same time that greater strength is given. This may be called the direct effect of humidification.

"Proper attention has not been given by mill men to the indirect effect of humidity which is upon the working capacity of the operative. . . Unbiased British officials and certain American engineers have demonstrated that, considered both immediately and ultimately, the direct or mechanical value of humidity works on parallel lines with the indirect or operative-working capacity effect, and that the best results in dividends are secured by considering direct and indirect (mechanical and personal) effects together; in other words, taking the resultant of the two working factors.

"In textile mill practice this means that ventilation and humidification must be considered as one and the same problem. . . To secure the largest profits on a given investment, it will pay the cotton manufacturer to consider not only the conditioning of the cotton fibres, but the health and working capacity of his operatives as part of a common practical problem.

"A British Departmental Committee on the Humidity and Ventilation in Cotton Weaving Sheds (January, 1909) reported against excessive percentages of humidity. The committee refers approvingly to the testimony of Dr. Pembrey, who conducted experiments on himself, soldiers and medical students, and who says that a standard below 70° wet bulb reading . . . would be 'to the advantage of both employer and employed.' Dr. Pembrey explained by say-

ing that 'at the lower temperature work could be done at a faster rate, more efficiently and with less fatigue, discomfort and injury to health.'"

The committee goes on to say: "We are kept from rising bodily temperature or fever by the process of evaporation of the impalpable perspiration. As we work and raise bodily heat this evaporation increases. If the atmospheric relative humidity be high, bodily evaporation is less rapid. The committee's experts found cases where bodily temperatures were raised three degrees by high relative humidity. Their recommendation was: "Keep your operatives comfortable and they can do more work. . . .

Mr. Michaelis states: "This leads directly to a consideration whether proper ventilation and humidity pay. Few people realize the cost of sick and physically inefficient operatives in terms of capital and plant, although the reduced output due to reduction of working force has long been appreciated. Whenever an operative in a cotton mill is absent, it stops a portion of the plant from earning his wages and also prevents the income for that time on an average investment of $2,000 in mill and machinery, and in many instances a much larger amount. There is no profit in idle machinery; there are no dividends when machinery is working poorly. Apply this to the operatives and the double value of proper ventilation and humidity is apparent. A skilled workman is hard to replace."

As to definite figures representing the effect on persons due to improved ventilation, Professor Woodbridge states: "Prison records show reduced death-rates chiefly as a result of effective ventilation, in one case from a yearly average of eigthy deaths to one of eight, each period covering the same and a considerable number of years."

In certain buildings, where the results of changing from poor to good ventilation have been carefully observed, a marked improvement in the general health of the occupants has been manifest. For example, the records of the United States Pension Bureau show that when the offices of the department were located in scattered and poorly ventilated buildings, 18,736 days were lost by employees

through illness in one year and about the same number for several successive years. When the department became established in its new well-ventilated quarters the loss was reduced to 10,114 days' absence on account of illness, the working force being larger and the work increased. The gain effected is not to be measured alone by the days' absence saved, but by the greater vitality and efficiency of the entire working force.

It is stated that improved ventilation resulted in the reduction in the death-rate in the Dublin Lying-in Hospital from 50 per cent. to 5 per cent. for equal terms of years.

In the Boston City Hospital good ventilation is said to have given reductions in death-rates from 44 to 13 per cent. in surgical wards and from 23 to 6 per cent. in other wards.

The improved physical conditions of teachers and pupils in moving from old inadequately ventilated school buildings to those equipped with modern and efficient systems is a well-known and admitted fact.

In regard to dwellings, investigations among the dwelling-houses of Dundee, Scotland, showed that with an increase in air-space per occupant, there was a great falling off in the death-rate. With air-spaces per person in the ratio of 4 to 1, for example, the death-rate was in the ratio of about 12 to 21, showing a reduction of over 40 per cent. in the case of the larger spaces.

Even though there be no method of ventilation provided, the mere abundance of space per occupant secures a certain air change, owing to the fact that no partitions, floors or ceilings are perfectly tight, hence the greater the space per occupant the greater the surface of surrounding walls, etc., and the greater the accidental air leakage, or spontaneous ventilation, as some put it.

Professor Winslow of the Massachusetts Institute of Technology, in a paper on "The Cash Value of Factory Ventilation," mentions that "efficient production requires skilled and practiced workers, in good physical condition, applying themselves with energy and enthusiasm to their

tasks. Irregularity of attendance and the physical sluggishness and nervous inattention which accompany lowered vitality mean direct money loss to the employer of labor, as well as a burden on the community at large."

As an example showing the results of improved ventilation, the paper calls attention to the operating room of the New England Telephone & Telegraph Co., at Cambridge, Mass., a long room having a capacity of 30,000 cu. ft., extending from front to back of a business block. Fifty or sixty women are employed in this room as operators. During the warmer months no difficulty has ever been experienced in ventilating the room by means of large windows at each end and by the use of electric fans. In winter, however, it was impossible to secure adequate natural ventilation without undue exposure to drafts.

In the spring of 1907 a simple but efficient system of artificial ventilation was installed. . . . A marked improvement in the comfort and general condition of the operators followed this change, and the betterment was sufficiently marked to show itself in a notably greater regularity of work.

Statistics collected and tabulated show that prior to the installation of the ventilating system for the three winter months, January, February and March inclusive, 4.9 per cent. of the force was absent in 1906 and 4.5 per cent. in 1907. With the ventilating system in use the absence for the same months in 1908 fell to only 1.9 per cent., a striking reduction.

Necessity for Ventilation

Having discussed the *"causes of atmospheric vitiation"* in occupied spaces and the *"effects of foul air on health and comfort,"* it would appear that the necessity of ventilation is obvious, nevertheless the slight apparent interest in certain sections of the country to make it compulsory leads me to dwell briefly on this phase of our subject.

Perhaps nothing has focused the attention of the general public on the necessity of fresh air so much as the crusade now being waged against tuberculosis. Dr. Woods

Hutchinson, in his book, "Preventable Diseases," brings out in a most vivid manner the wonderful changes wrought in the prevention and treatment of this disease. He says: "Fifty years ago belief was that consumption and all its attendant miseries were chiefly due to exposure to cold. Now we know that, on the contrary, abundance of pure, fresh air is the best cure for the disease, and foul air and overcrowding its chief cause. An almost equally complete about-face has been executed in regard to pneumonia. . .

"This much we are certain of already: that the majority of so-called 'colds' have little or nothing to do with exposure to a low temperature, that they are entirely misnamed, and that a better term for them would be 'fouls.' . . . . The best place to catch them is not out-of-doors, or even in drafty hallways, but in close, stuffy, infected hotel bedrooms, sleeping cars, churches and theatres.

"Two arguments in rebuttal will at once be brought forward, both apparently conclusive. One is that colds are vastly more frequent in winter, and the other that when you sit in a draft until you feel chilly, you inevitably have a cold afterward. Both these arguments alike, however, are based upon a misunderstanding. The frequency of colds in winter is chiefly due to the fact that, at this time of year, we crowd into houses and rooms, shutting the doors and windows in order to keep warm, and thus provide a ready-made hothouse for the cultivation and transmission from one to another of the influenza and other bacilli. . . .

"At the same time, we take less exercise and sit far less in the open air, thus lowering our general vigor and resisting power and making us more susceptible to attack. Those who live out-of-doors winter and summer, and who ventilate their houses properly, even in cold weather, suffer comparatively little more from colds in the winter time than they do in summer. . . ."

Dr. Hutchinson advises "living and sleeping as much as possible in the open air. This helps in several different ways: first, by increasing the vigor and resisting power of our bodies; second, by helping to burn up clean and rid our

tissues of waste products which are poisons if retained; third, by greatly reducing the risks of infection."

He advises us to learn to sit or sleep in a gentle current of air all the time we are indoors. He states: "We can plan to stop consumption by preventing the consumptive. A very small additional percentage of vigor or of resisting power, such as could be produced by but a slight improvement in the abundance of the food supply, the lighting and ventilating of the houses, the length and 'fatiguingness' of the daily toil might be the straw which would be sufficient to turn the scale and prevent the tuberculous individual from becoming consumptive.

"If the whole civilized community could be placed upon a moderate form of the open-air treatment, it would be so vastly improved in health, vigor and efficiency, and saved the expenditure of such enormous sums upon hospitals, poor relief and sick benefits, that it would be well worth all that it would cost, even if there were no such disease as tuberculosis on earth.

"The germs of tuberculosis will live for weeks and even months in dark, damp, unventilated quarters, just precisely such surroundings as are provided for them in the inside bedrooms of our tenements, and the dark, cellar-like rooms of many a peasant's cottage or farmhouse. In bright sunlight they will perish in from three to six hours; in bright daylight in less than half a day. . . One of the most important elements in the value of sunlight in the treatment of consumption is its powerful germicidal effect."

As to pneumonia the same writer says: "One thing was entirely overlooked until about twenty years ago: that this disease was due not simply to the depressing effects of cold, but to a specific germ (the pneumococcus of Fraenkel). This threw an entirely new light upon our elaborate weather-causation theories. And while these still hold the field by weight of authority and that mental inertia which we term conservatism, yet the more thoughtful physicians and pathologists are now coming to regard these factors as chiefly important according to the extent to which we are crowded together in often badly lighted

and ill-ventilated houses and rooms, with the windows and doors shut to save fuel." Dr. Hutchinson asserts that the heavy crop of pneumonia in January, February and March is the logical result of the seed-sowing and forcing of the preceding two or three months.

Macfie in his recent book observes: "All the writers on ventilation assume that ventilation which causes any perceptible motion of cool air is not permissible. But why? Simply because the unnatural habits of so-called civilized peoples render them unduly sensitive to draughts; and, through erroneous reasoning, cold air and draughts are considered dangerous."

On the other hand, Billings says: "We may write and talk as much as we please about the horrors of bad air and the importance of good ventilation, but we shall never induce people to sit in cold draughts and shiver for the sake of pure air."

As an engineer I will say that could the doctors convert the people at large to their views as to sitting in gentle draughts, our work would be much simplified, for one of the limiting conditions in the ventilation of rooms is the absence of perceptible draughts which is insisted upon by the occupants and required by compulsory ventilation laws. With the opinion at present held by people as to sitting in draughts, it would, I believe, be useless to expect that a ventilating system involving disagreeable draughts would continue to be operated in any building where persons have to sit for any length of time.

In conclusion, adequate ventilation should be considered a necessity in spite of the increased cost over heating only. It contributes to health, efficiency and happiness by making us more vigorous, keeping our bodies in a condition capable of warding off disease.

How foolish to build beautiful churches, fine public buildings, theatres or schools and disregard the provision of a proper ventilating equipment, which, perhaps, contributes more than any other expenditure to the real end in view! How often we are unable to enjoy entertainments owing to faulty ventilation or its utter absence!

Compulsory Ventilation

Admitting, as I trust we all do, the necessity of providing for the ventilation of many classes of buildings, let us see what results have been achieved by the advocates of ventilation as evidenced by complusory requirements in force in the several States of the Union.

The Committee on Complusory Ventilation of the American Society of Heating and Ventilating Engineers in reply to a recent inquiry reports that:

"Laws regulating the ventilation of school buildings are in effect in Massachusetts, New York, New Jersey, Pennsylvania, Virginia, Utah and Minnesota.

"Work has been done looking toward the enactment of compulsory ventilation laws in the States of Illinois, Indiana and Wisconsin.

"In Connecticut, Indiana and Vermont rulings have been promulgated by the State Board of Health in an attempt to regulate the ventilation of schools, but there is no law providing a fine for non-enforcement of the provision.

I understand there is little or no activity in other States in regard to compulsory ventilation. The laws in force relate either solely or chiefly to the ventialation of public buildings.

The customary standard for these buildings is the supply of 30 cu. ft. of fresh air per minute per occupant. This corresponds to a trifle more than seven parts of carbon dioxide in 10,000 in the room air. Outdoor air contains three to four parts by volume of CO_2 in 10,000.

The committee mentioned suggests "that the bills presented in future shall state clearly what buildings or classes of buildings are referred to, as they may include municipal buildings, court houses, jails, city and county hospitals, asylums, reformatories, houses of refuge, as well as State prisons, hospitals, asylums, institutions of learning, including normal schools, colleges and public and high schools. It is well also to call attention to the many private institutions, schools, hospitals, theatres, auditoriums and places

of amusement and learning, none of which seem to come directly under the regulations, but should be ventilated under the law."

As to factory ventilation.

While much has been done to compel manufacturers to provide exhaust ventilating apparatus for the removal of harmful dust and fumes, much remains to be done to make compulsory the ventilation of factories or shops where the workers are, in many cases crowded together, and where the conditions are often frightfully unsanitary.

Professor Winslow, in the paper previously mentioned, says:

"When one finds the tuberculosis death-rate in certain minor industries four and five times the normal, and in large and important industries 50 per cent. to 100 per cent. higher than the normal, it is clear that the campaign against tuberculosis is incomplete without a systematic attempt to improve the conditions of factory life. Improved factory conditions mean first and foremost improved ventilation."

For factory ventilation a minimum air supply of 1000 cu. ft. per minute per occupant, corresponding to 10 parts CO_2 in 10,000 by volume, is considered by many to represent an attainable and practicable minimum of ventilation for factory workers.

The recently published twenty-second annual report of the Commissioner of Labor of the United States states that laws in reference to the ventilation of factories are in force in the States of Alabama, Connecticut, Delaware, Illinois, Indiana, Iowa, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Jersey, New York, Oregon, Pennsylvania, South Dakota, Ohio, Tennessee, Washington, West Virginia and Wisconsin.

It is to be noted that the factory ventilation laws referred to relate chiefly to the air-space per occupant and the removal of dust or fumes, rather than to any definite air supply per occupant.

Conclusion

In this discussion I have stuck pretty closely to the subject assigned to me, "Ventilation in its Relation to Health." It would have been far easier for me as an engineer, and doubtless more interesting to you, had I described methods of ventilation instead of limiting the discussion to the causes of atmospheric vitiation, to the effects of foul air on health and comfort, to the necessity of ventilation, and to a statement of what has been accomplished in the way of compulsory ventilation.

Since "necessity is the mother of invention," if people are convinced of the necessity of ventilation, there will be no difficulty in providing the means, even to the utmost refinements. If ventilation could be had for little or no cost above that for heating alone, there would not be the "hue and cry" against it on the part of those whose "pocket nerve" is touched.

The fact, however, that in cold climates adequate ventilation costs money should not be allowed to stand in the way of its more general compulsory adoption. Those who are most in need of it are, as a rule, least able to demand it, hence the necessity of the strong protecting the weak through the enactment of legislation to secure to children in schools, to adults in public buildings and to workers in factories and shops an adequate volume of pure, fresh air. It is not pleasant to consider that in crowded unventilated rooms the air must be breathed and rebreathed, nor is it pleasant to consider the other causes of atmospheric vitiation within enclosures as pointed out.

Some writers speak of "crowd-poison," a not inapt title to that component of the atmosphere in enclosed spaces which causes discomfort, and results in lessened efficiency and vitality on the part of the occupants, predisposing them to disease.

I wish to emphasize as strongly as I can the necessity of the adequate ventilation of buildings. To keep the at-

mosphere of an occupied room wholesome, a change of air must be secured; if the space is so large, the number of occupants so few and the porosity of the enclosing walls or the leakage around openings such that spontaneous ventilation is sufficient, well and good. This will, however, suffice only in rare instances; some dependable means must in most cases be provided to furnish a minimum volume of fresh air per minute for each occupant and for each gas-jet, the volume to be based on the air quality which it may be desirable and practicable, all things considered, to maintain in the room, the quality or condition of the atmosphere to be measured by the commonly accepted carbonic dioxide standard.

Let us remember that adequate ventilation is the "ounce of prevention" that will often turn the balance in favor of health and keep us fit for the battle of life. Its importance cannot be overstated.